



**UNIVERSITI PUTRA MALAYSIA**

**DEVELOPMENT OF A CARTESIAN PAINTER ROBOT FOR  
CONSTRUCTION INDUSTRY**

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**DEVELOPMENT OF A CARTESIAN PAINTER ROBOT FOR  
CONSTRUCTION INDUSTRY**

**By**

**A. K. M. PARVEZ IQBAL**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia  
in the Fulfillment of the Requirements for the Degree  
of Master of Science**

**November 2002**



***TO MY DEAREST FATHER, MOTHER, SISTER AND BROTHER***



Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science.

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**Chairman: Dr. Ishak Bin Aris**

**Faculty: Institute of Advanced Technology**

Nowadays robots are widely used in many applications such as in factories, the mining industries, the automobile industry etc. Currently, the application of robot is still not widely implemented in construction industry. In construction industry, robots are designed to increase speed and improve the accuracy of construction field operations. It can also be used to do hazardous and dangerous job in construction. For example, house painting is done manually. This process can be simplified using a special dedicated robot. It is very difficult and troublesome for human to work in an upright position especially for painting, cleaning and screwing in the ceiling for a long time. Painting in an upright position is also very dangerous for the eyes. To overcome this difficulty, a painter robot system is proposed and developed.

The main objective of this project is to develop a three-degree of freedom (DOF) painter robot and its intelligent system. In order to achieve the main objective, the following works are carried out:

Development of the mechanical structure of the robot. This includes the positioning module and end-effector module. The positioning module is divided into three parts

namely, X-axis module, Y-axis module and Z- axis module. Development of the electrical and electronic system of the robot. These include its power distribution system, sensor system, motor driver system, electro-pneumatic system and programmable logic controller and development of the controlling program of the robot.

The proposed painter robot has three degree of freedom (DOF). For X direction, a single-phase induction motor and a chain-sprocket mechanism are used. Two limit switches and two electronic sensors are used to limit the movement in X direction. Another sensor is used to position the robotic arm along the X direction. For Y direction, two limit switches are used to limit the movement in Y direction. Two sensors are used to protect the robotic arm along the Y direction. The single-phase motor with an inverter is utilized to control the speed of the robot in Y direction. For Z direction, a parallelogram structure and a ball-screw mechanism are used in this project. A single-phase brake motor and a photoelectric sensor are used to control the position in Z direction. Two limit switches are used to limit the movement in Z direction. The proposed robot is used to paint the ceiling of the houses. The paint is sprayed by the robot automatically using the pneumatic system.

The software part involves the design and development of the system control software. The system control software is created using FP WIN GR PLC programming software. This project implements the Matsushita NAIS FP0 programmable logic controller (PLC) to control the overall system of the machine.

From the tests conducted on the painter robot, it is observed that the robot is operating according to its original plan.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains.

**PEMBINAAN ROBOT PENGECAT KARTESIAN  
UNTUK INDUSTRI PEMBINAAN**

**Oleh  
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Dalam era ini robot digunakan secara meluas dalam berbagai bidang seperti perkilangan, perlombongan dan sebagainya. Ketika ini penggunaan robot dalam industri pembinaan belum lagi digunakan secara meluas. Dalam industri pembinaan, robot direka untuk meningkatkan kepantasan dan memperbaiki ketepatan operasi. Ia juga boleh digunakan untuk melakukan kerja-kerja yang berbahaya dan berisiko tinggi dalam pembinaan. Sebagai contohnya, kerja-kerja mengecat rumah dilakukan secara manual. Proses ini boleh dipermudahkan dengan menggunakan suatu robot istimewa yang berdedikasi. Adalah sangat sukar bagi manusia untuk bekerja pada posisi yang tinggi terutamanya untuk mengecat, mencuci, mengetatkan skru pada siling dalam jangkamasa yang lama. Untuk mengatasi kesulitan ini, suatu robot pengecat telah dicadangkan dan dibina.

Objektif utama projek ini ialah untuk membina suatu robot pengecat yang mempunyai tiga darjah kebebasan (DOF) dan juga sistem pintar bagi robot tersebut. Untuk mencapai objektif ini, kerja-kerja berikut dilakukan, iaitu: Pembinaan struktur mekanikal robot. Ini termasuklah 'positioning module' dan 'end-effector module'. 'Positioning module' dibahagikan kepada tiga bahagian, iaitu modul paksi-X, modul

paksi-Y dan modul paksi-Z. Pembinaan sistem elektrik dan elektronik robot tersebut. Ini termasuklah sistem pembahagian kuasa, sistem penderia, sistem pemanduan bermotor, sistem elektro-pneumatik dan 'programmable logic controller' dan pembinaan program robot tersebut.

Robot pengecat yang dicadangkan mempunyai tiga darjah kebebasan (DOF). Bagi arah X, suatu motor 'induction' satu fasa dan mekanisma 'chain-sprocket' digunakan. Dua suis penghad dan dua penderia elektronik digunakan untuk menghadkan pergerakan dalam arah X. Satu penderia lain digunakan untuk meletakkan tangan robot di sepanjang arah X. Bagi arah Y, dua suis penghad digunakan untuk menghadkan pergerakan dalam arah Y. Dua penderia digunakan untuk melindungi tangan robot di sepanjang arah Y. Motor satu fasa dengan 'inverter' digunakan untuk mengawal kepantasan robot dalam arah Y. Bagi arah Z, suatu struktur 'parallelogram' dan mekanisma 'ball-screw' digunakan dalam projek ini. Motor brek satu fasa dan penderia fotoelektrik digunakan untuk mengawal posisi dalam arah Z. Dua suis penghad digunakan untuk menghadkan pergerakan dalam arah Z. Dua suis penghad digunakan untuk menghadkan pergerakan dalam arah Z. Robot tersebut digunakan untuk mengecat siling rumah kos rendah. Cat tersebut akan disembur secara automatik dengan menggunakan sistem pneumatik.

Bahagian perisian melibatkan penciptaan dan pembinaan perisian sistem pengawalan. Perisian sistem pengawalan dicipta dengan menggunakan program perisian FP WIN GR PLC. Projek ini menggunakan program 'logic controller' (PLC) Matsushita NAIS FPO untuk mengawal keseluruhan sistem mesin tersebut.



Daripada ujian yang dijalankan ke atas robot pengecat tersebut, didapati bahawa robot tersebut beroperasi mengikut pelan asal.

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I certify that an Examination Committee met on 14<sup>th</sup> November 2002 to conduct the final examination of A. K. M. Parvez Iqbal on his Master of Science thesis entitled "Development of a Cartesian Painter Robot for Construction Industry" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

A. K. M. Pervez Iqbal

A. K. M. PARVEZ IQBAL

Date: 26-11-2002

## TABLE OF CONTENTS

	<b>Page</b>
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	vii
APPROVAL SHEETS	xi
DECLARATION	xiii
LIST OF TABLES	xvii
LIST OF FIGURES	xviii
LIST OF ABBREVIATIONS	xxii
LIST OF SYMBOLS	xxiii

## CHAPTER

<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Introduction	1.1
	1.2 Problem Statement	1.2
	1.3 Objectives	1.4
	1.4 Overview of the Project	1.5
	1.5 Limitation of the Robot	1.8
	1.6 Layout of the Thesis	1.8
 <b>2</b>	 <b>LITERATURE REVIEW</b>	
	2.1 Automation and Robots	2.1
	2.2 Painting Machine	2.3
	2.3 Robot Classification	2.12
	2.3.1 Drive Technology	2.12
	2.3.2 Work-envelope Geometries	2.14
	2.3.3 Motion and Control Method	2.19
	2.4 Dynamic Analysis of Parallelogram Structure	2.19
	2.5 Intelligent Robotic System	2.24
	2.5.1 Sensing and Effecting	2.24
	2.5.2 Knowledge about the Environment (World Model)	2.25
	2.5.3 Interpreting	2.25
	2.5.4 Generating	2.26
	2.5.5 Reasoning	2.26
	2.6 Components of Control System and Automation	2.27
	2.6.1 The Control of Motor	2.27
	2.6.1.1 AC Induction Motor	2.27
	2.6.1.2 DC Servo Motor	2.28
	2.6.1.3 Stepper Motor	2.29
	2.6.2 Sensors	2.30



2.6.3	Solenoids Devices	2.31
2.6.4	Power Transmission Component	2.33
2.6.4.1	Belts and Chains	2.33
2.6.4.2	Lead Screw and Ball Screw	2.33
2.6.5	Electro-pneumatic System	2.35
2.7	Robot Controller and Programming Software	2.36
2.7.1	The Smart Step Controller (3-Axis Controller)	2.37
2.7.2	Programmable Logic Controller (PLC)	2.37
2.7.2.1	Basis of Programmable Logic Controller	2.38
2.7.2.2	Types of Inputs and Outputs	2.39
2.7.2.3	Hardware Control System	2.40
2.7.2.4	Programmable Control System	2.40
2.7.2.5	The Components of PLC	2.41
2.7.2.6	The Advantage and Disadvantages of PLC	2.42
2.7.3	Robot Languages	2.43
2.8	Summary of Literature Review	2.45

### 3 METHODOLOGY

3.1	Overview	3.1
3.2	Mechanical Design	3.4
3.2.1	Positioning Module	3.5
3.2.1.1	Design of X-axis Module	3.5
3.2.1.1.1	X-axis Motor Torque Calculation	3.6
3.2.1.2	Design of Y- axis Module	3.11
3.2.1.2.1	The Selection of the Y-axis Module Guide Rod	3.11
3.2.1.2.2	Y-axis Motor Torque Calculation	3.14
3.2.1.3	Design of Z-axis Module	3.16
3.2.1.3.1	Z-axis Harden Guide Rod Selection	3.16
3.2.1.3.2	Z-axis Motor Torque Calculation	3.18
3.2.2	End-Effector Module	3.20
3.2.2.1	Design of End-Effector Module	3.20
3.2.3	Dynamic Formulation of the Parallelogram Structure	3.22
3.3	Electrical and Electronic System	3.28
3.3.1	Power Supply Module	3.28
3.3.2	Programmable Logic Controller (PLC)	3.29
3.3.3	Sensing Module	3.32
3.3.3.1	Electrical Sensor Circuitry	3.33
3.3.3.1.1	Photoelectric Sensors	3.33
3.3.3.1.2	Inductive Sensor	3.34
3.3.3.1.3	Limit Switch	3.35
3.3.4	Electro-Pneumatic System Design	3.36
3.3.5	Control of AC Induction Motor	3.39
3.3.6	Control Panel	3.41
3.4	Software Development	3.42
3.4.1	Flow Chart	3.42



3.4.2	Ladder Diagram Construction	3.49
3.4.3	PLC Programming Development Software	3.54
3.4.4	Creating and Editing the Program	3.55
3.5.5	Compiling Program	3.56
3.4.6	The Input and Output Port Indication	3.56
<b>4</b>	<b>RESULT AND DISCUSSION</b>	
4.1	X -axis Module	4.1
4.1.1	Test Conducted to the X-axis Module	4.6
4.1.1.1	Repeated Positioning Accuracy Test for X-axis	4.7
4.1.1.2	X-axis Positioning Sensor Test	4.8
4.1.1.3	Test for Protection Sensor in X Direction Movement	4.10
4.2	Y-axis Module	4.11
4.2.1	Test Conducted to the Y-axis Module	4.14
4.2.1.1	Repeated positioning Accuracy Test for Y-axis	4.14
4.2.1.2	Test of Protection Sensor in Y Direction Movement	4.15
4.3	Z-Axis Module	4.17
4.3.1	Test Conducted to the Z-axis Module	4.21
4.3.1.1	Repeated Positioning Accuracy Test for Z-axis	4.21
4.3.1.2	Ceiling Detection Sensor Test	4.22
4.4	End-Effector Module	4.24
4.4.1	Test Conducted to the End-Effector Module	4.25
4.4.1.1	The Single Acting Cylinder Test	4.25
4.4.1.2	Pressure Sensor Test	4.26
4.4.1.3	Pneumatic Control System	4.28
4.5	AC Induction Motor Drivers	4.29
4.6	System Control Software	4.32
4.7	System Integration	4.37
4.7.1	Painting Test	4.40
4.7.2	Cost of the Project	4.41
<b>5</b>	<b>CONCLUSION AND RECOMMENDATION</b>	
5.1	Conclusion	5.1
5.2	Recommendation	5.3
	<b>REFERENCES</b>	R.1
	<b>APPENDIXES</b>	
	Appendix A: Mechanical Drawing of the Painter Robot	A
	Appendix B: PLC Programming	B
	Appendix C: Mechanical Components and Design Chart	C
	Appendix D: Electrical Components	D
	Appendix E: Pneumatic Components	E
	<b>BIODATA</b>	F



## LIST OF TABLES

	<b>Page</b>
Table 2.1: Robot work envelopes based on major axes	2.15
Table 3.1 Input and output mapping of the system	3.57
Table 4.1: Testing result of the X- axis-positioning sensor	4.9
Table 4.2: Testing result of the protection sensor in X-direction movement	4.10
Table 4.3 The testing result of protection sensor in Y-direction	4.16
Table 4.4: The testing result of ceiling detecting sensor	4.23
Table 4.5: The operation status of the pressure sensor	4.27
Table 4.6: The testing result of the motor driver	4.31
Table 4.7: Type and function of the relays	4.32
Table 4.8: The I/O mapping of the FP0 PLC	4.32
Table 4.9: Robot specification	4.39
Table 4.10 Cost of the project	4.41



## LIST OF FIGURES

	<b>Page</b>
Figure 1.1: The overview of the project	1. 5
Figure 1.2: The general structure of the system	1.7
Figure 2.1:Relative cost-effectiveness of soft automation	2.2
Figure 2.2: Cartesian robot	2.16
Figure 2.3: Cylindrical robot	2.16
Figure 2.4: Spherical robot	2.17
Figure 2.5: SCARA robot	2.18
Figure 2.6: Articulated robot	2.18
Figure 2.7: Parallelogram structure	2.19
Figure 2.8: Solenoids: (a) Basic construction; (b) relay switch; (c) solenoid valve	2.32
Figure 2.9: Push and pull solenoid and force/ displacement characteristics	2.32
Figure 2.10: The lead screw and ball screw	2.34
Figure 2.11: Basic of programmable logic controller	2.38
Figure 2.12: Type of input and output signal	2.39
Figure 2.13: Signal from switch or sensors	2.39
Figure3.1: Project activities	3.2
Figure3.2: Block diagram of the robotic system of this project	3.4
Figure 3.3: The base frame	3.5
Figure 3.4:Total system of the project	3.6
Figure 3.5: The Y axis module and Z- axis module	3.14
Figure 3.6: The motor, bearing, chain and sprocket arrangement	3.16



Figure 3.7: The end effector module	3.20
Figure 3.8: The air compressor, paint tank and spray gun	3.21
Figure 3.9: The parallelogram structure of the system.	3.22
Figure 3.10: Power supply distributions of the painter robot	3.29
Figure 3.11: Basic structure of PLC	3.31
Figure 3.12: Photoelectric sensor	3.33
Figure 3.13: Wiring diagram for the connection to the power supply unit and PLC	3.34
Figure 3.14: The inductive sensor	3.35
Figure 3.15: Wiring diagram for connection of limit switch to the power supply unit and PLC	3.36
Figure 3.16: Signal flow diagram and pneumatic elements	3.37
Figure 3.17: (a) Pneumatic system;	3.37
Figure 3.17: (b) (b) Electronic control circuit	3.38
Figure 3.18a: Wiring diagram of motor and relays for the connection to PLC	3.40
Figure 3.18b: Wiring diagram of motor and inverter for the connection to PLC	3.40
Figure 3.19: Block diagram of the control panel	3.41
Figure 3.20: The flow chart of the program	3.43
Figure 3.21: The FPWIN GR programming Edit window	3.54
Figure 3.22: Edit window of the FPWIN GR	3.55
Figure 3.23: Edit window before compiling	3.56
Figure 4.1: Slider guide ways and runner block	4.2
Figure 4.2: The first mounting used to hold the Y-axis module	4.3
Figure 4.3: The first mounting used to hold the Y-axis module	4.4
Figure 4.4: The chain bearing and idler arrangement	4.5

Figure 4.5: The platform control panel and painting tanc.	4.5
Figure 4.6: The motor and coupling of X-axis	4.6
Figure 4.7: Repeated positioning length	4.7
Figure 4.8: Testing of X axis positioning sensor	4.9
Figure 4.9: The inductive proximity sensor	4.9
Figure 4.10: The testing of protection sensor	4.10
Figure 4.11: Protection sensor in X-direction	4.11
Figure 4.12: The guide rod and linear bushing	4.12
Figure 4.13: The Y-axis module	4.13
Figure 4.14: Motor and coupling of Y-axis module	4.13
Figure 4.15: Repeated positioning length of Y-axis module	4.15
Figure 4.16: The testing of protection sensor	4.16
Figure 4.17: The protection sensor of Y-axis module	4.17
Figure 4.18: Parallelogram structure	4.18
Figure 4.19: The bottom part of Z-axis module	4.19
Figure 4.20: Guide rod and bushing	4.19
Figure 4.21: Ball screw and nut.	4.20
Figure 4.22: Motor and coupling of Z-axis module	4.20
Figure 4.23: Repeated positioning length	4.22
Figure 4.24: The testing of protection sensor	4.23
Figure 4.25: The ceiling-detecting sensor	4.24
Figure 4.26: Cylinder and spray gun	4.25
Figure 4.27: (a) Control of single acting cylinder; (b) single acting cylinder advances when valve is actuated	4.26

Figure 4.28: The testing of the pressure sensor	4.27
Figure 4.29: The resting of the pneumatic control valve	4.28
Figure 4.30: (a) The testing of Z-axis brake motor; (b) The testing of X-axis motor;	4.30
Figure 4.30 (c): The testing of Y-axis motor	4.31
Figure 4.31: Homing function	4.33
Figure 4.32: Start and reset function	4.33
Figure 4.33 Shift register function	4.34
Figure 4.34: Interlock function	4.34
Figure 4.35: Painting in forward mode function	4.34
Figure 4.36: X –axis positioning function	4.35
Figure 4.37: Painting in backward mode function	4.35
Figure 4.38: Break opening function	4.35
Figure 4.39: X-axis forward mode function	4.35
Figure 4.40: Z-axis forward mode function	4.36
Figure 4.41: Pneumatic valve opening function	4.36
Figure 4.42: Y-axis forward mode function	4.36
Figure 4.43: Y –axis backward mode function	4.36
Figure 4.44: Z-axis motor run mode function	4.37
Figure 4.45: X-axis motor run mode function	4.37
Figure 4.46: Indicator light opening function	4.37
Figure 4.47: The mechanical structure of the system	4.38
Figure 4.48: The control panel	4.38
Figure 4.49: The painted area	4.40

## LIST OF ABBREVIATIONS

AC	Alternative current
AML	A manufacturing language
CAD	Computer aided design
CCW	Counter clock wise
DC	Direct current
DOF	Degree of freedom
I/O	Input and output
MINT	Motion interpreter
PC	Personal computer
PLC	Programmable logic controller
RIA	Robotic industries association
RPP	Revolute, prismatic, prismatic
RRP	Revolute, revolute, prismatic



## LIST OF SYMBOLS

$K$	Kinetic energy
$T$	Torque
$J$	Inertia
$T$	Time
$\omega$	Angular velocity
$g$	Gravity constant
$W_L$	Weight of the load
$W_S$	Weight of the sprocket
$W_C$	Weight of the chain
$F$	Frictional Force
$R$	Radius of sprocket
$V$	Linear velocity
$\rho$	Density
$R$	Radius of shaft
$L$	Length
$\mu_s$	Static coefficient of friction
$d$	Diameter of shaft
$M$	Maximum moment
$\delta_d$	Design Stress
$m$	Mass
$\delta_u$	Ultimate stress



$\delta_y$	Yield stress
$e$	Efficiency of ball-screw
m	Meter
n	Newton
$p$	Pitch
mm	Millimeter
cm	Centimeter
$L_n$	Measured distance
$M_1$	Motion of parallelogram link
$M_2$	Motion of parallelogram link
$V$	Potential energy.